

AQA A-LEVEL PHYSICS

GIVEN AND HIDDEN FORMULAE

COMPONENT CODE 7407 AND 7408

Note for user:

This resources was created by an A Level Student (momondi on TES) in 2017 in preparation for upcoming A level Exams. As such if there are any errors, do contact the author of this resource.

This is intended as a guide for useful formulae that can be used in exam questions and to help build understanding on the topics studied at AQA

Resources referred to making this resource:

CGP A Level Year 1 – The Complete Course for AQA

CGP A Level Year 2 – The Complete Course for AQA

Advanced Physics For You

AQA Specification

AQA A Level Physics formula sheet

$$\text{Specific Charge} = \frac{Q}{m}$$

This is the charge to mass ratio for a particle/nucleus/ion. (Ckg^{-1})

$$E_{min} = 2E_0$$

Pair Production:

The minimum energy needed for pair production is equal to double the rest energy of one particle produced

$$E = hf = \frac{hc}{\lambda}$$

The energy of a photon of EM radiation is directly proportional to its frequency

$$\phi = hf_0$$

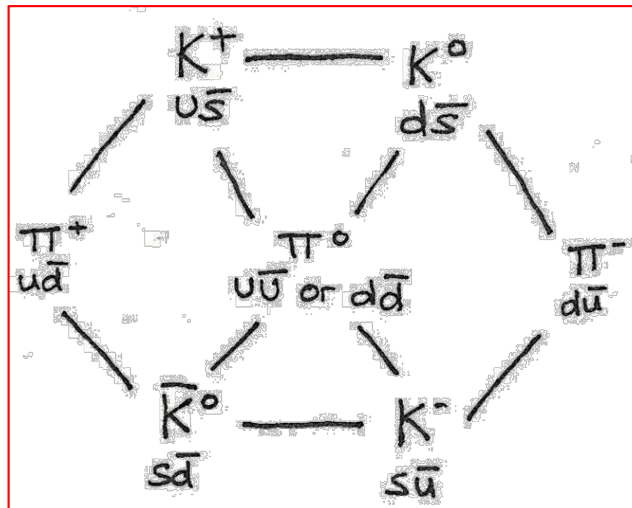
The **work function**, ϕ is the **minimum amount of energy** needed to **release an electron** from the **surface of a metal**

The **threshold frequency**, f_0 is the **minimum frequency of EM radiation** needed to **release an electron** from the **surface of a metal**

Planck's constant

$$h = 6.63 \times 10^{-34} Js$$

QUARK STRUCTURE OF ALL MESONS



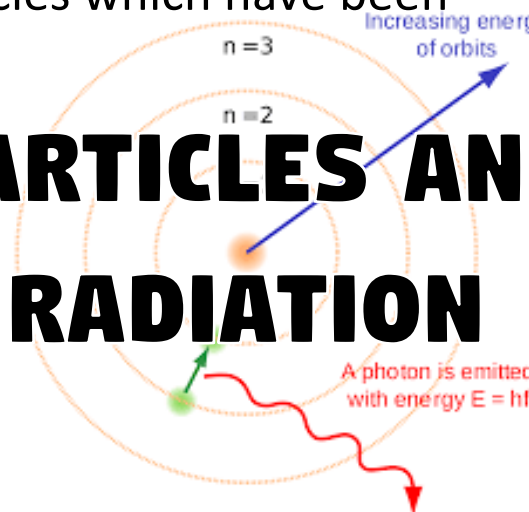
$$1eV = 1.6 \times 10^{-19} J$$

$$hf = E_1 - E_2$$

The de-excitation of an electron between two energy levels will emit a photon of EM radiation.

An electron must gain a specific amount of energy in order to be excited to a higher energy level

PARTICLES AND RADIATION



$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Particles with a larger momentum will have a smaller de Broglie wavelength.

$$E_{k(max)} = eV_s$$

Stopping potential, V_s is the potential difference needed to stop the fastest moving electron in a photocell experiment

$$hf = \phi + E_{k(max)}$$

The kinetic energy of photoelectrons is up to a maximum because:

- Photons are absorbed by electrons on a one to one basis
- Some electrons are deeper in the metal than others
- This means that they require more energy than the work function to be released, so their kinetic energy will be lower than those from the surface

Key

Blue equation – Given formulae

Red equation – Not given formulae

$$f = \frac{1}{T}$$

$$c = f\lambda$$

$$\text{Energy of a wave} \propto (\text{amplitude})^2$$

$$n = \frac{c}{c_s}$$

$$\text{phase difference} = \frac{2\pi d}{\lambda}$$

$$I = \frac{P}{A}$$

Intensity is the energy transferred per second over an area of 1m^2 (Wm^{-2})

The refractive index must always be higher than 1! The higher the number, the more optically dense the medium is

The frequency of the first harmonic on a string

$$f = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$$

$$\mu = \frac{m}{L}$$

Where μ is the total mass of the string divided by its total length (mass per unit length, kgm^{-1}).

The frequency of the 2nd, 3rd, 4th harmonics etc will be a multiple of the first harmonic

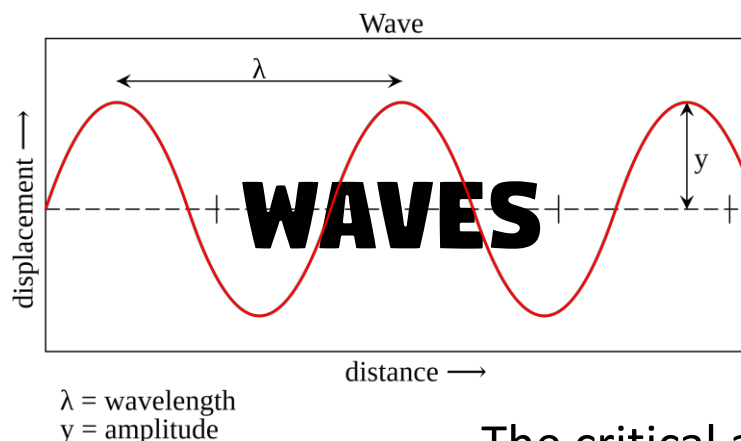
$$d \sin \theta = n\lambda$$

Diffraction Gratings

- n stands for the order, the position of a maxima
- For a fixed slit width, d , light with a longer wavelength will be diffracted more

$$\text{relative refractive index} = \frac{n_2}{n_1}$$

n_2 is the more dense medium in this case



$$\sin \theta_c = \frac{n_2}{n_1}$$

Note: If you get math error, the refractive indexes are the wrong way round

The critical angle can only occur when light goes from a more dense to a less dense medium.

This means that n_2 **must be less dense in this case**

$$w = \frac{\lambda D}{s}$$

Young Double Slit Experiment

- w is the fringe spacing
- D is the distance from the screen to the slit
- s is the slit separation

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Snell's law

θ_1 is the angle of incidence
 θ_2 is the angle of refraction

Key

Blue equation – Given formulae

Red equation – Not given formulae

S.U.V.A.T Equations

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$E_k = \frac{1}{2}mv^2$$

$$\Delta E_p = mg\Delta h$$

Remember to consider which forms energy is transferred into before making equations equal!

$$s = ut + \frac{1}{2}at^2$$

$$s = \left(\frac{u + v}{2} \right) t$$

$$Moment = Fd$$

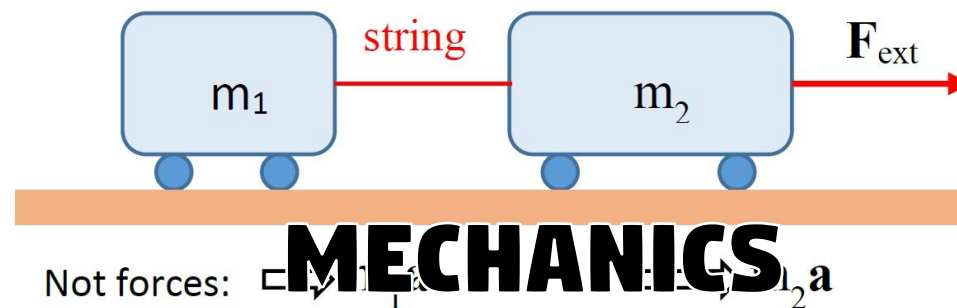
A moment is the force multiplied by the distance perpendicular from the line of action of the force to the pivot. Measured in Nm .

Assumptions made

- No air resistance acting
- Object is moving uniformly so the **acceleration is constant**

$$v = \frac{\Delta s}{\Delta t}$$

$$a = \frac{\Delta v}{\Delta t}$$



Newton's Second Law

$$F = \frac{\Delta(mv)}{\Delta t}$$

$$F = ma$$

The **RESULTANT FORCE**, F , is directly proportional to the rate of change of an object's momentum

$$W = mg$$

If air resistance is not acting and an object falls due to gravity, then its mass does not affect its acceleration

Forces: $\rightarrow \mathbf{F}_{21}$ $\mathbf{F}_{12} \leftarrow$
 $\xrightarrow{\hspace{1.5cm}} \mathbf{F}_{\text{ext}}$

$$p = mv$$

Momentum is an object's mass multiplied by velocity. It is measured in $kgms^{-1}$ **Vector quantity**

$$F\Delta t = \Delta(mv)$$

Impulse is the resultant force on an object multiplied by the length of time it acts for. It can be measured in Ns or $kgms^{-1}$. **Vector quantity.**

$$W = F_S \cos \theta$$

Work done is the transfer of energy from one form to another when a force is moved through a distance. Measured in joules, J

The $\cos \theta$ indicates the force must be resolved in the direction of motion

$$P = \frac{\Delta W}{\Delta t} = Fv$$

Power is the energy transferred per second or the rate at which work is done. It is measured in Watts, W

In $P = Fv$, F is the force causing the motion. v is the velocity in that direction

$$efficiency = \frac{useful\ power}{input\ power}$$

Key

Blue equation– *Given formulae*

Red equation – Not given formulae

$$\rho = \frac{m}{V}$$

Density is the mass per unit volume of a material, a measure of how much mass each cubic metre of volume contains. It is measured in kgm^{-3}

$$\rho_{alloy} = \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}$$

All this means is find the **total mass** of the two materials, and **divide by the total volume** they take up, to find the overall density of an alloy

Hooke's Law

$$F = k\Delta L$$

The force applied in stretching/compressing a material is directly proportional to its extension until the limit of proportionality.

$$E = \frac{1}{2} F \Delta L$$

$$E = \frac{1}{2} k (\Delta L)^2$$

Energy stored by a stretched/compressed material (obeying Hooke's Law)

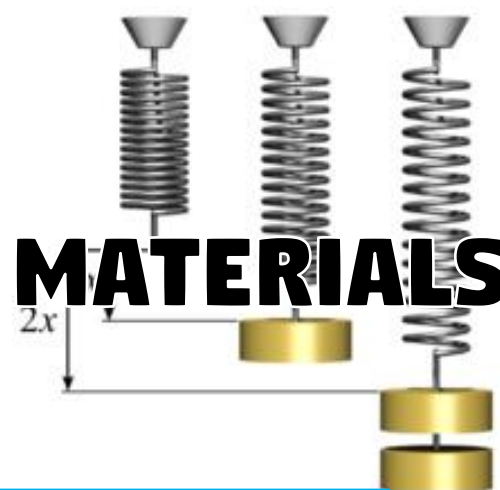
$$Tensile\ stress = \frac{F}{A}$$

This is the **force applied** in deforming a material **divided by its cross-sectional area**. Measured in Nm^{-2} or Pa

$$Tensile\ strain = \frac{\Delta L}{L}$$

This is the extension of a material divided by its original length. It has no units as it is a ratio

$$Energy\ per\ unit\ volume = \frac{1}{2} \times stress \times strain$$



$$Young\ modulus = \frac{Stress}{Strain}$$

$$Young\ modulus = \frac{F \times L}{A \times \Delta L}$$

The Young Modulus of a material is a measure of how difficult it is to change the shape of a material. The higher the value, the stiffer the material. It is measured in Pa .

The gradient of a stress-strain graph gives the Young Modulus. **The gradient is only taken up until the limit of proportionality**

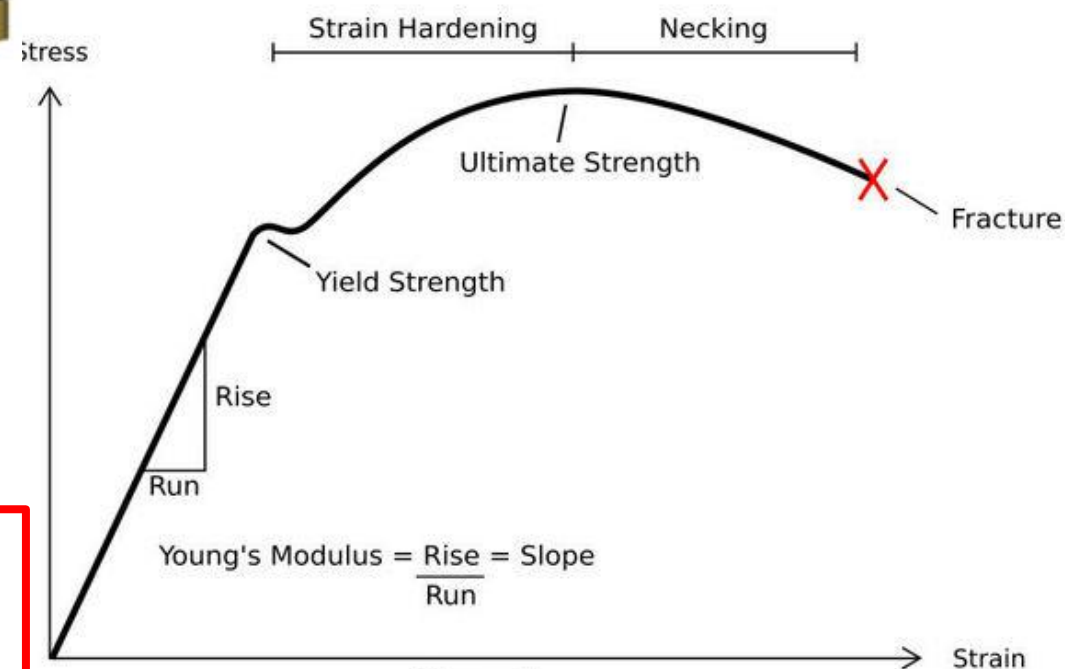


Figure 1

Key

Blue equation – Given formulae

Red equation – Not given formulae

$$I = \frac{\Delta Q}{\Delta t}$$

Current is the rate of flow of charge passing a point per second.
Measured in amps, A or Cs^{-1}

$$V = \frac{W}{Q}$$

Potential difference is the work done per coulomb of charge passing between two points in a circuit. It is measured in volts, V or JC^{-1}

$$R = \frac{V}{I}$$

Resistance is the ratio of the potential difference across a component to the current passing through it. It is measured in Ω

$$\rho = \frac{RA}{L}$$

Resistivity is a property specific to a material which measures the resistance to the flow of current when taking into account the cross sectional area and its length. It is measured in Ωm .

$$\varepsilon = \frac{E}{Q}$$

Electromotive force (e.m.f), ε is the amount of electrical energy supplied per coulomb of charge from a source. It is measured in volts, V

Rule for the total resistance of a series circuit

$$R_T = R_1 + R_2 + R_3 + \dots$$

Rule for the total resistance of a parallel circuit

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

$$P = IV = I^2 R = \frac{V^2}{R}$$

Electrical Power is the rate of energy transfer from an electrical component.

Doubling the current through a component will quadruple the power losses of a component. (Useful to know for A2 when studying transformers)

$$E = ItV$$

Total energy transferred by a component in a given time

$$V_{out} = V_{in} \times \frac{R_1}{R_1 + R_2}$$

Potential dividers are used to vary the potential difference supplied by a source to different components.

They split the potential difference across each component in order to obtain an output p.d.

ELECTRICITY

$$\varepsilon = I(R + r)$$

$$\varepsilon = V + v$$

If a power supply has internal resistance, some energy is wasted per coulomb of charge. This is referred to as lost volts. The useful energy transferred per coulomb of charge to the rest of the circuit is called the terminal p.d.

Key

Blue equation – Given formulae

Red equation – Not given formulae

$$\omega = \frac{\theta}{t}$$

Angular speed is the angle an object rotates through per second. It is measured in radians per second (rads^{-1})

$$\text{arc length} = r\theta^*$$

* θ must be in radians!

$$\text{circumference of circle} = 2\pi r$$

$$1\text{radian} = \frac{\pi}{180^\circ}$$

$$F = \frac{mv^2}{r} = m\omega^2 r$$

The **resultant force** which causes an object to undergo circular motion is called the centripetal force.

Resolve forces carefully to check which forces are contributing to the centripetal force!

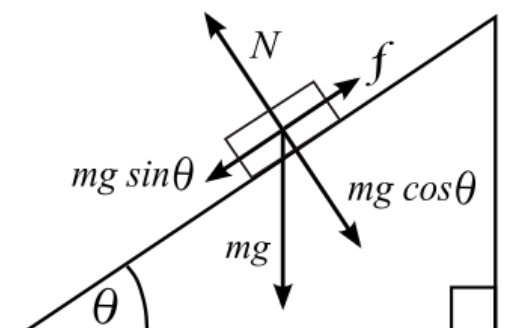
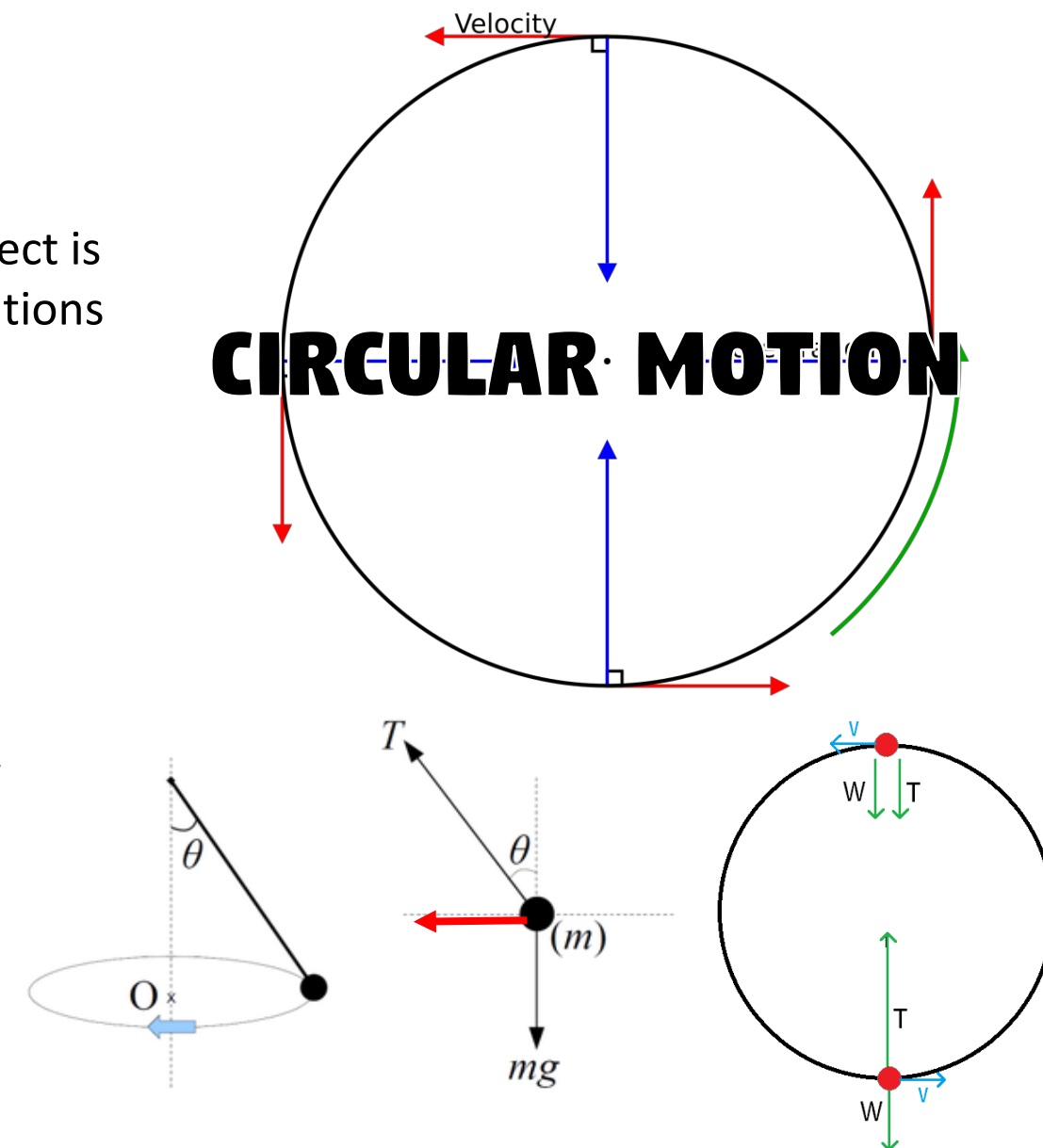
$$\omega = 2\pi f$$

The frequency of a rotating object is the number of complete revolutions per second (revs^{-1} or Hz)

$$a = \frac{v^2}{r} = \omega^2 r$$

If an object's direction is constantly changing, its velocity is changing. If its velocity is changing over time, then it is accelerating.

This is called centripetal acceleration (ms^{-2})



Key

Blue equation – Given formulae

Red equation – Not given formulae

$$a = -\omega^2 x$$

For an object to undergo SHM, its acceleration must be directly proportional to its displacement from the equilibrium position in the opposite direction.

$$a_{max} = \omega^2 A$$

The acceleration of the object will be at a maximum when it is at its maximum amplitude

$$x = A \cos \omega t$$

At $t = 0$, the object is at maximum displacement.

This is equal to the amplitude, A

$$v = \pm \omega \sqrt{A^2 - x^2}$$

$$v_{max} = \omega A$$

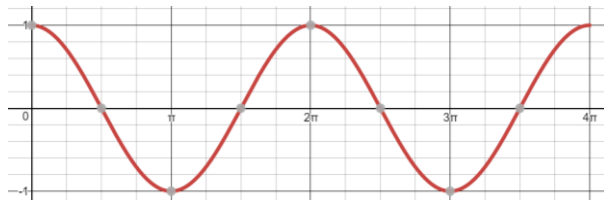
$$T = 2\pi \sqrt{\frac{l}{g}}$$

For a simple pendulum, the time period is only affected by the length of the pendulum and the gravitational field strength

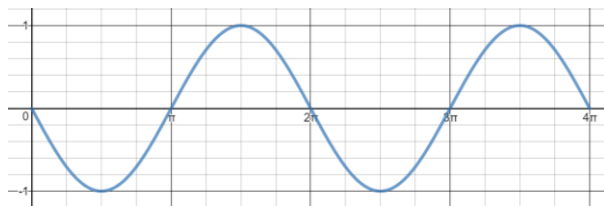
The velocity of the object will be at a maximum when it is passing through the equilibrium position

The gradient of the displacement graph will give you the velocity at any point.

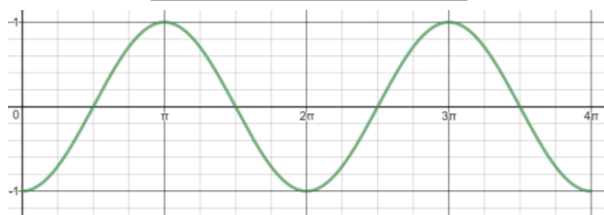
Displacement



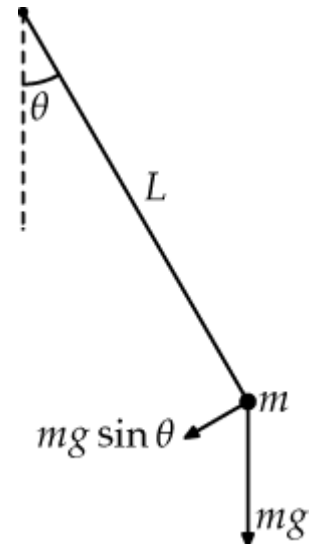
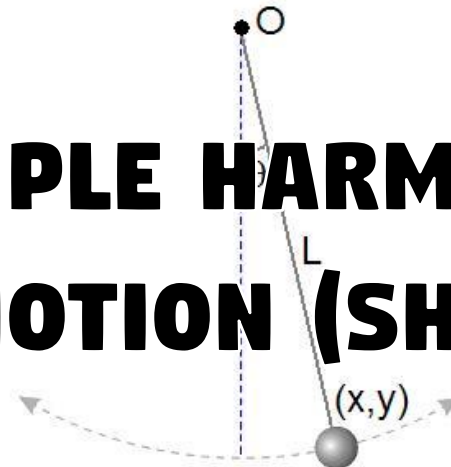
Velocity



Acceleration

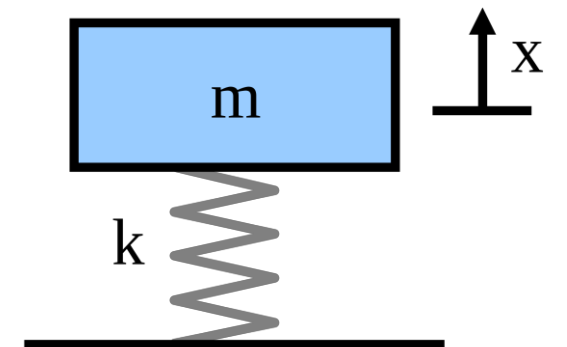


SIMPLE HARMONIC MOTION (SHM)



$$T = 2\pi \sqrt{\frac{m}{k}}$$

For a mass-spring system, the time period is only affected by the object's mass and the spring constant of the spring



Key

Blue equation – Given formulae

Red equation – Not given formulae

$$K = C + 273$$

$$N = nN_A$$

N_A is Avogadro's number, the number of molecules present in 1 mole. N is the number of molecules and n is the number of moles

Absolute zero is the point at which all molecules have zero kinetic energy

$$n = \frac{m}{M_r}$$

(Relative) Molecular mass, M_r is the sum of the atomic masses which make up a molecule (measured in grams)

A change of $1K$ equals a change of $1^\circ C$

The molar mass, M_u , is the mass of one mol of a *substance* (usually measured in $kgmol^{-1}$, but check units in questions!)

$$Q = mc\Delta\theta$$

Specific heat capacity is the energy needed to raise the temperature of 1kg of a substance by $1K$ (or $1^\circ C$).

It is measured in $Jkg^{-1}K^{-1}$ or $Jkg^{-1}^\circ C^{-1}$

$$Q = ml$$

Specific latent heat is the energy needed per kg to be gained or lost in order to change state. It is measured in Jkg^{-1} .

l_f means the latent heat of fusion (solid to liquid)

l_v means the latent heat of vaporisation (liquid to gas)

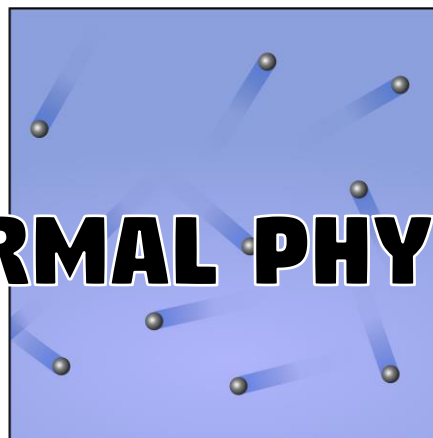
$$\Delta W = p\Delta V$$

This equation only applies if there is a constant pressure and temperature.

$$\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$$

The average kinetic energy of a **single molecule of gas** is directly proportional to temperature of the gas.

THERMAL PHYSICS



$$pV = nRT$$

$$pV = NkT$$

For an ideal gas, these laws show three experimental relationships:

- $P \propto \frac{1}{V}$
- $V \propto T$
- $P \propto T$

$$\frac{pV}{T} = \text{constant}$$

$$pV = \frac{1}{3}N\overset{\text{Mass of ONE MOLECULE}}{\color{red}m}(c_{rms})^2$$

The kinetic theory equation demonstrates that that for N molecules of gas at a given volume, the mass and the r.m.s. speed affect the pressure

Key

Blue equation – Given formulae

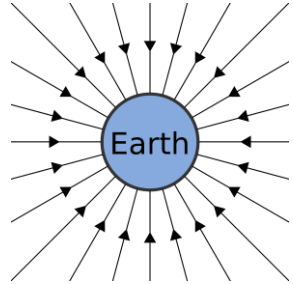
Red equation – Not given formulae

$$F = \frac{Gm_1m_2}{r^2}$$

Force between two masses is directly proportional to the product of their masses and inversely proportional to the distance between them squared.

Vector quantity

RADIAL FIELD



$$g = \frac{GM}{r^2}$$

Gravitational field strength in a radial field is inversely proportional to the distance from the mass squared

$$\Delta W = m\Delta V$$

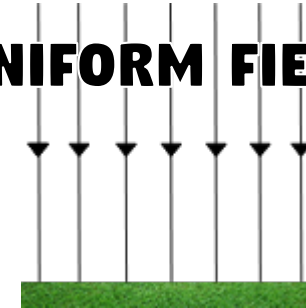
Gravitational Potential is the work done per unit mass in bringing a point mass from infinity to a point in a gravitational field (Jkg^{-1})

Scalar quantity

$$V = -\frac{GM}{r}$$

Gravitational Potential is always negative as by convention, zero potential is at a point which is an infinite distance away from a gravitational field

UNIFORM FIELD

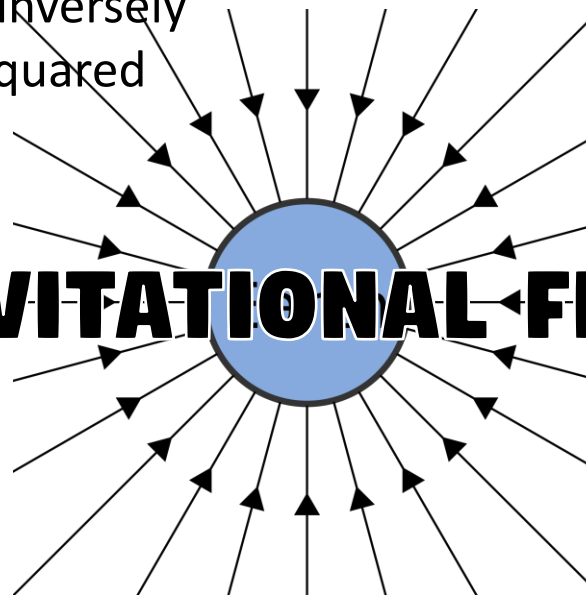


$$g = \frac{F}{m}$$

Gravitational field strength is the force per unit mass (Nkg^{-1})

Vector quantity

GRAVITATIONAL FIELDS



$$g = -\frac{\Delta V}{\Delta r}$$

The gradient of a graph showing distance against gravitational potential gives you the gravitational field strength.

The area of a graph showing gravitational field strength against distance gives you gravitational potential

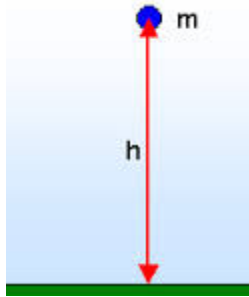
Key

Blue equation – Given formulae

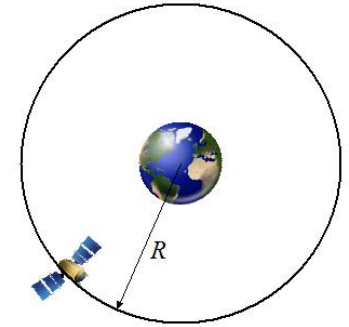
Red equation – Not given formulae

$$E_p = -\frac{Gm_1m_2}{r}$$

Gravitational Potential Energy in a radial field



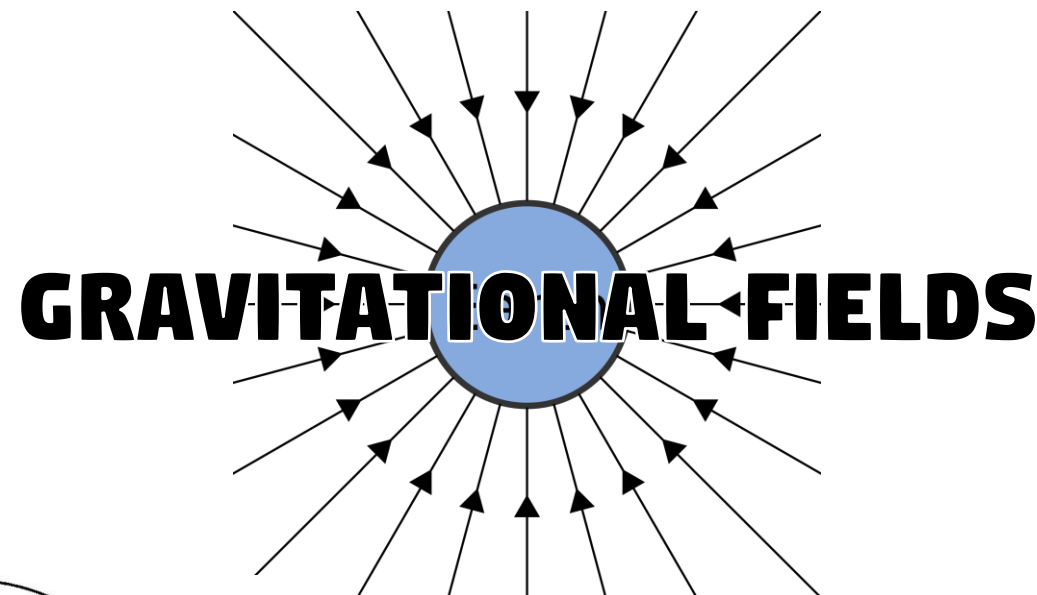
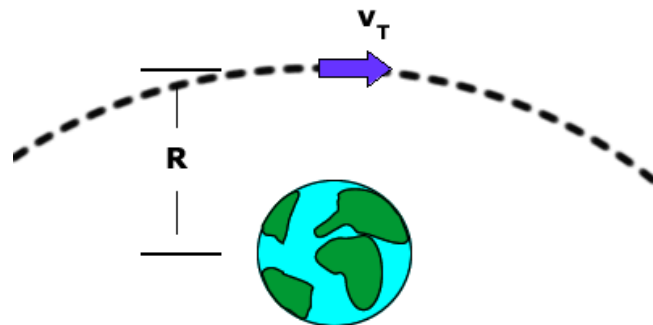
$$T^2 = \frac{4\pi^2}{GM} r^3$$



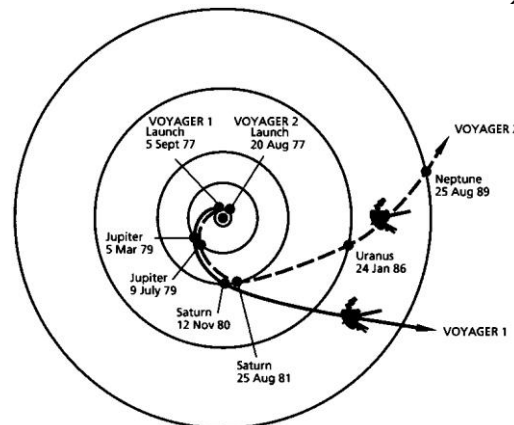
$$v = \sqrt{\frac{GM}{r}}$$

The orbital speed of a satellite is inversely proportional to the square root of the radius of its orbit

The time period of a satellite's orbit around a planet squared is directly to proportional to the radius of its orbit cubed (Circular motion applies)



$$v = \sqrt{\frac{2GM}{r}}$$



The escape velocity of an object is the velocity needed for an object to be completely free of a gravitational field from a planet

Key

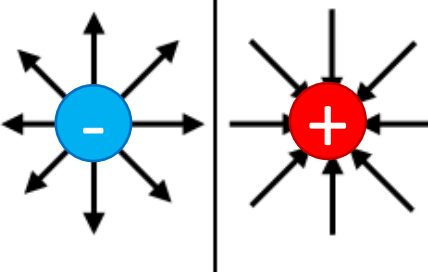
Blue equation – Given formulae
Red equation – Not given formulae

$$F = \pm \frac{kQ_1Q_2}{r^2}$$

Force between two charges is directly proportional to the product of their charges and inversely proportional to the distance between them squared.
Vector quantity, +ve force = repulsion, -ve force = attraction

$$* k = \frac{1}{4\pi\epsilon_0}$$

RADIAL FIELD

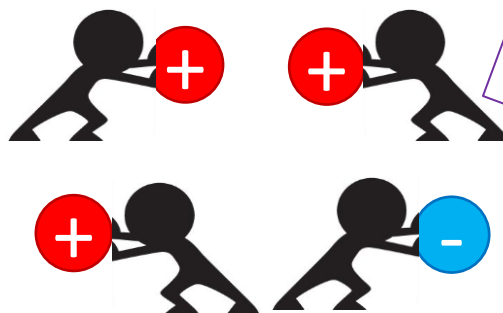
$$E = \frac{kQ}{r^2}$$


Electric field strength in a radial field is inversely proportional to the distance from the charge squared

$$\Delta W = Q\Delta V$$

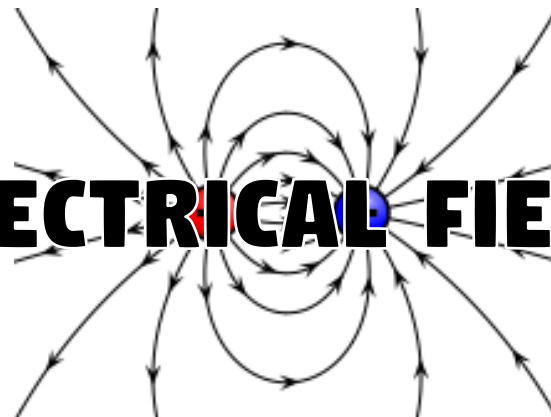
Electric Potential is the work done per unit charge in bringing a positive charge to infinity from a point in an electric field (JC^{-1} or V) **Scalar quantity**

$$V = \pm \frac{kQ}{r}$$

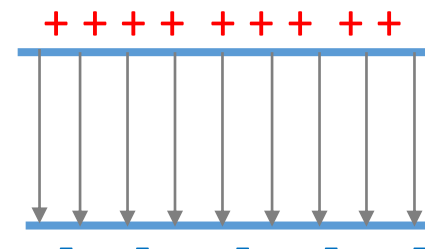


Depending on the charge, electric potential may be positive or negative as it is the work done in **bringing a positive point charge** to a point in a field

ELECTRICAL FIELDS



UNIFORM FIELD



$$F = EQ$$

$$E = \frac{V}{d}$$

Electric field strength is the force per unit charge (NC^{-1}) **Vector quantity**

$$E = \frac{\Delta V}{\Delta r}$$

The gradient of a graph showing distance against electric potential gives you the electric field strength

The area of a graph showing electric field strength and distance gives you electric potential

$$E_p = -\frac{kQ_1Q_2}{r}$$

Electric Potential Energy in a radial field

High potential situation

Key

Blue equation – Given formulae

Red equation – Not given formulae

$$C = \frac{Q}{V}$$

Capacitance is the charge stored per unit potential difference by a capacitor (*Farads, F or CV⁻¹*)

$$\epsilon_r = \frac{\epsilon_1}{\epsilon_0}$$

$$\epsilon_r = \frac{Q}{Q_0}$$

$$\epsilon_r = \frac{C}{C_0}$$

Relative permittivity is the ratio between the permittivity of a material and the permittivity of free space (*Fm⁻¹*)

$$E = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}$$

The gradient of a graph showing voltage against charge will give you the capacitance

The area under graph will give you the energy stored by the capacitor

$$\text{time constant} = RC$$

The time constant is the time taken for the voltage/current/charge of a capacitor to reach $\frac{1}{e}$ of its original value ($\approx 37\%$)

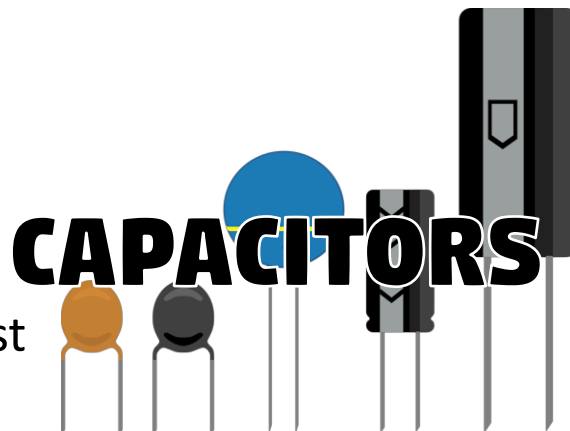
$$C = \frac{A\epsilon_0\epsilon_r}{d}$$

Capacitance is directly proportional to the area of the plates, and inversely proportional to the distance between them

The higher the relative permittivity of a material, the higher the capacitance

$$I = I_0 e^{-\frac{t}{RC}}$$

The rate of flow of charge will always decrease at an exponential rate, regardless of whether a capacitor is charging or discharging



DISCHARGING CAPACITORS

$$Q = Q_0 e^{-\frac{t}{RC}}$$

$$V = V_0 e^{-\frac{t}{RC}}$$

For a discharging capacitor, the rate at which charge and voltage change over time obey an exponential decay relationship

CHARGING CAPACITORS

$$Q = Q_0 \left(1 - e^{-\frac{t}{RC}}\right)$$

$$V = V_0 \left(1 - e^{-\frac{t}{RC}}\right)$$

$$T_{\frac{1}{2}} = \ln 2 RC$$

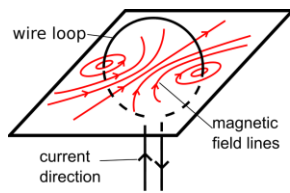
The half life of a capacitor is the time taken for the voltage/current/charge of a capacitor reaches half of its original value

Key

Blue equation – Given formulae

Red equation – Not given formulae

$$F = BIl$$



The force on a current carrying wire is directly proportional to the magnetic flux density (field strength), the current in the wire and the length of the wire.

Magnetic Flux Density is measured in *Teslas, T* or $NA^{-1}m^{-1}$ **Vector quantity**

$$\Phi = BA$$

Magnetic Flux is the total magnetic flux passing through a given area. It is measured in *Webers, Wb* or Tm^{-2} **Scalar quantity**

$$[N\Phi] = BAN \cos \theta$$

Magnetic flux linkage is the total magnetic flux which flows through a cross section of a coil of wire. It is measured in *Wb turns*

$$\varepsilon = N \frac{\Delta\Phi}{\Delta t}$$

The induced emf across a conductor is directly proportional to the rate of change of flux linkage in a magnetic field

$$\varepsilon = BAN\omega \sin \omega t$$

The emf of a coil rotating uniformly in a magnetic field is dependant on the flux linkage and the angular speed.

$$F = BQv$$

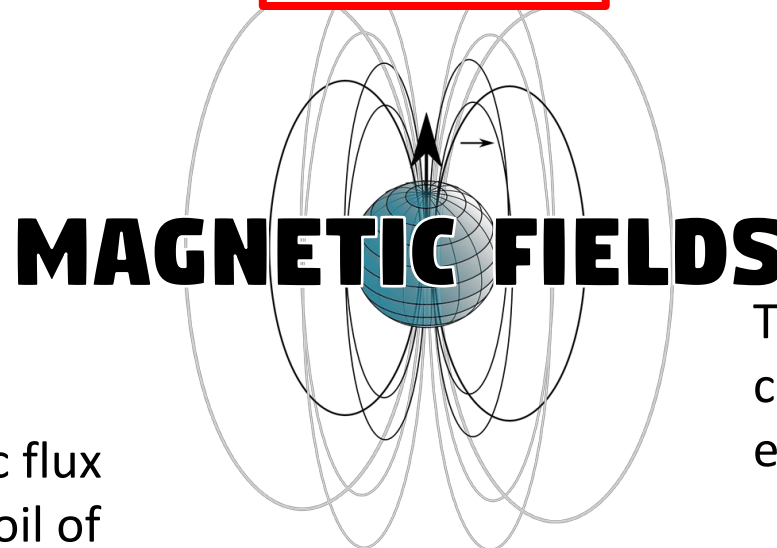
The force on a charge in a magnetic field is affected by the magnetic flux density, the size of the charge and the velocity of its motion perpendicular to the field.

$$r = \frac{mv}{BQ}$$

The radius of a charged particle moving through a magnetic field is directly proportional to its momentum and inversely proportional to the magnetic flux density and its charge.

$$T = \frac{2\pi m}{BQ}$$

The time period of a charged particle moving through a magnetic field is independent of its velocity.



$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

The r.m.s. current/voltage of an A.C supply can be directly compared to its DC equivalent

$$P = I_{rms}V_{rms}$$

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$Efficiency = \frac{I_s V_s}{I_p V_p}$$

Assuming that a transformer is 100% efficient, the ratio of the number of turns on the primary and secondary coil is equal to the ratio of their voltages

Key

Blue equation – Given formulae

Red equation – Not given formulae

Alpha Decay, α

Nucleon number decreases by 4
Proton number decreases by 2

Beta minus decay, β^-

Nucleon number stays the same
Proton number increases by 1

Beta plus decay, β^+

Nucleon number stays the same
Proton number decreases by 1

$$I = \frac{k}{x^2}$$

The intensity of radiation is inversely proportional to the distance from the source squared

$$Initial E_k = \frac{kQ_1Q_2}{r}$$

When determining the radius of a nucleus through electron diffraction, the minimum angle of diffraction is given as follows

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

$$A = \lambda N$$

The distance of closest approach for a nucleus can be found when an alpha particle with kinetic energy is fired to a nucleus. The distance is where $E_k = E_p$

$$\sin \theta \approx \frac{1.22\lambda}{2R}$$

The activity, A of a radioactive sample is directly proportional to the number of nuclei present. It is measured in becquerels, Bq

Nuclear decay is random and spontaneous. The decay constant, λ is the probability of a nucleus decaying in a given time.

It is measured in s^{-1}

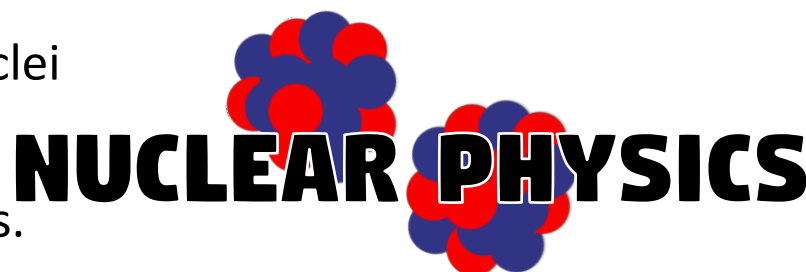
$$N = N_0 e^{-\lambda t}$$

The number of nuclei and activity of radioactive substance follow an exponential decay relationship over time

$$A = A_0 e^{-\lambda t}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

The half life of a radioactive substance is the time taken for the activity/ number of radioactive nuclei present to half



$$R = R_0 A^{\frac{1}{3}}$$

The radius of a nucleus is directly proportional to the cube root of an atoms nucleon number

$$E = mc^2$$

This equation can be used to:

- Find the binding energy of a nucleus – the energy that would be needed to separate a nucleus into its individual parts
 - Calculate the energy released in a nuclear reaction
- m is the **mass difference** or the **mass defect** in kg

$$1u = 931.5MeV = 1.661 \times 10^{-27} kg$$

1 atomic mass unit has a binding energy of $931.5MeV$

Key

Blue equation – Given formulae

Red equation – Not given formulae